HASP Student Payload Application for 2007

Payload Title: University of Alabama – Student High-Altitude Power Experiments (UA-SHAPE)		
Payload Class: (circle one) Small Large	Institution: University of Alabama	Submit Date: 14 December 2006

Project Abstract

The proposed experiments will examine the effectiveness of different power storage devices under actual high-altitude conditions. Battery efficiency is significantly reduced at temperatures typically experienced during high-altitude flights. The University of Alabama (UA) team proposes the flight of several small regenerative power systems to examine the performance of NiMH, NiCd, Li Ion, and supercapacitors. The state of charge of these devices will be recorded during flight and conclusions regarding performance will be drawn from the experimental data. In addition, a control set of fully charged devices will be flown and the state of charge of these devices will be examined during the post-flight analysis.

The UA team has been structured to include both a management team and a technical team. The management team will focus on the budgetary issues, workforce development, and information technology. The technical team will be responsible for the detailed design of the experiments, the integration of the experimental module, module flight operations, and post-flight analysis.

The UA-SHAPE module will require the use of the HASP's 28 VDC power supply to power control and data logging electronics. A DB9 connector will be used to transmit real-time telemetry via the HASP's telemetry system via an RS232 link.

Team Name: UA-SHAPE	Team or Project Website: http://space.eng.ua.edu/SHAPE

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PROJECT DESCRIPTION

Energy management systems for vehicles that are operating at high-altitudes are essential to ensure sustained flight in these rugged conditions. Because of the limited renewable energy available to the vehicle, it is imperative that the energy management system capture energy, store energy and use it as efficiently as possible. Energy is typically captured using a solar array, which converts the sun's radiation to energy that can be used by the vehicle. The energy is typically stored in batteries or other devices such as supercapacitors. The use of batteries for renewable energy vehicles is common. However, because the temperature at high-altitudes is so low [1], the storage capacities of the batteries can be reduced by 30 percent or more [2]. The amount of decreased storage capacity of different types of batteries has been researched at cryogenic temperatures [3], however, examining the effect of high-altitude conditions on rechargeable batteries can give great insight into the performance of energy storage systems for future high-altitude vehicles. An emerging technology for energy storage is the use of supercapacitors. Supercapacitors are often used in vehicle applications to boost the power density and increase the energy storage capacity. Initial studies have shown promising results for the use of supercapacitors at cryogenic temperatures [4].

The overall goal of this experiment is to examine the effectiveness of several different energy storage devices at actual high-altitude conditions. To achieve this goal, the following tasks will be completed:

1. Design and fabricate four instrumented regenerative power systems capable of providing information as to the state of charge of different energy storage devices as a function of time. The specific energy storage devices to be considered in this project will be a lithium-ion battery (Li Ion), a nickel-metal-hydride (NiMH) battery, a nickel cadmium (NiCd) battery, and a supercapacitor.
2. Integrate the above-mentioned regenerative power systems into a single experimental module, the UA-SHAPE module. Note that the UA-SHAPE module will also include the control case energy storage devices. These devices will not be charged or discharged during the experiment but the state of charge of each of these devices will recorded before and after the experiments for comparison.
3. Test the UA-SHAPE module in a laboratory environment to determine the baseline performance of the respective energy storage devices.
4. Integrate the UA-SHAPE module into the HASP.
5. Practice pre-flight/flight/post-flight procedures.
6. Collect data during the 2007 HASP flight.
7. Analyze the data from Task 3 and Task 6. This analysis will include a comparison of each of the energy storage devices as a function of time, of data from the flight relative to laboratory data, and of data from the active energy storage devices relative to the control energy storage devices.
8. Draw conclusions as to the relative effectiveness of each of the energy storage devices.
9. Identify area where the experimental apparatus and the experimental procedure can be improved.

References

[1] A. Colozza, “Initial Feasability Assessment of a High Altitude Long Endurance Airship”, *NASA/CR-2003-212724*, 2003.
[2] H. Oman, “Aerospace & Military Battery Applications,” *IEEE AESS Systems Magazine*, Vol. 17, No. 10, October 2002, pp. 29-35.
[3] W. Jackson et al., “Characteristics of Semiconductor Devices at Cryogenic Temperatures,” *Proceedings of the 31st Intersociety Energy Conversion Engineering Conference*, Vol. 2, August 1996, pp. 676-681.
[4] E. Schempp and W. Jackson, “Systems Considerations in Capacitive Energy Storage,” *Proceedings of the 31st Intersociety Energy Conversion Engineering Conference*, Vol 2., August 1996, pp. 666-671.

PAYLOAD DESCRIPTION

The payload for the University of Alabama HASP experiment will consist of a 8 small, flexible solar arrays, 8 AA size batteries/supercapacitors and the applicable circuit boards that will control the energy flow and log the specific variables of interest for the project team. The solar arrays are commercial off the shelf (COTS) solar arrays. They are 11.43 cm long and 3.7 cm wide. Two solar cells will be used for each battery under study and will be mounted in the applicable location on the experiment package. The batteries that will be used are also COTS and will be purchased from local retailers. All of the batteries that will be tested are 5 cm long and 1.45 cm in diameter and are standard AA size. The supercapacitor that will be used is an Elna Dynacap DZ series electrolytic supercapacitor. The capacitor is 50mm long and 35mm in diameter. Circuit boards with as many surface mount components as possible will be used to fabricate the power distribution and control circuitry. It is anticipated that three boards will be used for all of the circuitry needed for the experiment.

TEAM STRUCTURE

The UA-SHAPE team will be structured as shown in Figure 1 and as described below.

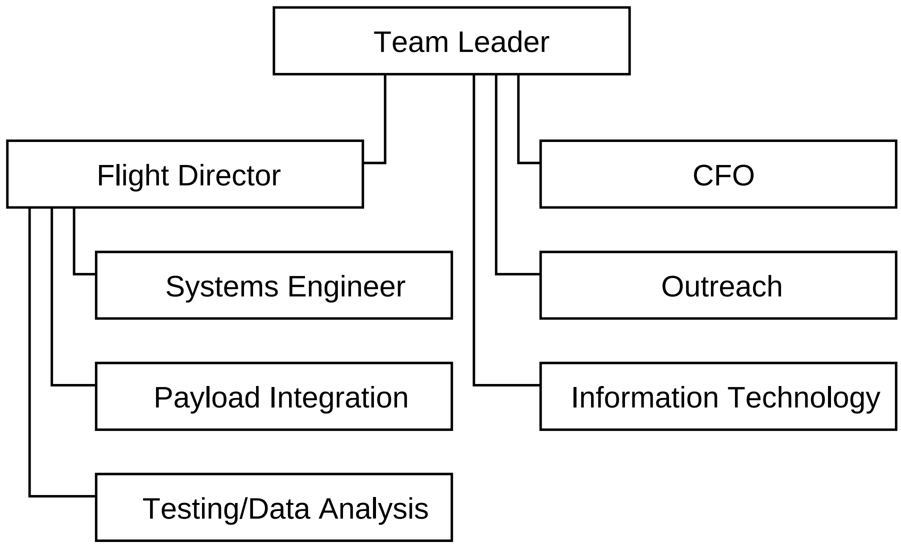


Figure 1. UA-SHAPE team structure.

Management Team

Team Leader: Rachael Greene

The team leader will be responsible for the overall execution of UA-SHAPE project. This individual will also be responsible for:

- *assigning specific tasks not specifically given to other team leaders,*
- *securing funds for the UA-SHAPE project, and*
- *maintaining a result-oriented/focused group effort.*

Chief Financial Officer (CFO): Damien Brown

The CFO will be responsible for maintaining financial records. This individual will also be responsible for:

- *communicating to the individual group leaders the funds available for specific activities,*
- *purchasing/securing items from vendors, and*
- *maintaining an up-to-date project financial balance sheet.*

Outreach Officer: Jason Hunter

The Outreach Officer will be responsible for all workforce development activities. This individual will also be responsible for:

- *organizing outreach activities at local K-12 schools as well as regional community colleges,*
- *publicizing the UA-SHAPE project though the UA College of Engineering's Public Relations Office and through local media outlets, and*
- *establishing longitudinal tracking procedures.*

Information Technology (IT) Officer: Shawn Thomas

The IT Officer will be responsible for maintaining communications between the respective project group members. This individual will also be responsible for:
- updating the project web site,
- maintaining an archive of all documents pertaining to the UA-SHAPE project, and
- ensuring all software needed during the course of the project is available to team members.

Technical Team

Flight Director: Ryan Davis

The Flight Director will have decision making authority for all technical decisions during the course of the project. This individual will also be responsible for:
- maintaining a detailed (up to date) experiment specification sheet,
- establishing written pre-flight, flight, and post-flight procedures, and
- leading the UA effort during the flight of the HASP.

Systems Engineer: Jeremy Hubinger

The Systems Engineer will be responsible for the detailed design of the experimental apparatus. This individual will also be responsible for:
- communicating all design information to the Flight Director,
- performing tests on UA-SHAPE module component systems, and
- incorporating recommendations of the Testing/Data Analysis Specialist into the UA-SHAPE module.

Payload Integration Officer: Justin Owen

The Payload Integration Officer will be responsible for ensuring the smooth integration of the UA-SHAPE module into the HASP. This individual will also be responsible for:
- overseeing any modifications to the UA-SHAPE module required for integration,
- coordinating the UA integration effort with personnel from the HASP program , and
- documenting all integration activities.

Testing/Data Analysis Specialist: Rachael Greene

The Testing/Data Analysis Specialist will ensure that the UA-SHAPE module functions properly during the HASP flight. This individual will be responsible for:
- developing a testing schedule for all components of the UA-SHAPE module,
- analyzing test data from the above-mentioned component tests,
- recommending possible design modifications to the Systems Engineer, and
- analyzing the data obtained during the HASP flight.

TIMELINE

A tentative schedule of the proposed UA-SHAPE project is provided in figure 2. The definitions of the respective tasks were provided in the Project Description section of this proposal.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct
Task 1	o o	o o o o	o o o o							
Task 2			o o o o	o o o o	o o o o					
Task 3					o o o o	o o o o	o o o o			
Task 4								o o o		
Task 5							o o	o o o o		
Task 6									o	
Task 7									o o o o	
Task 8										o o
Task 9										o o

Figure 2. Timeline for the UA-SHAPE project.

HASP INTEGRATION

It is expected that 4 students and 2 UA faculty/staff members will travel to LSU in July 2007 for the integration of the UA-SHAPE module onto the HASP. It is anticipated that 6 to 7 students and 2 UA faculty/staff members will travel to Ft. Sumner for the flight operations in September 2007.

PAYLOAD SPECIFICATION

A block diagram of the main experiment is shown in Figure 3. In this experiment, three different rechargeable battery types are charged during the day using small flexible solar panels and discharged during the night phase to examine their storage and discharge performance. Their charging characteristics are controlled by a DC-DC converter and the amount they are discharged through a resistive load is also governed by a DC-DC converter. The DC-DC converter that will be used in this application is a Buck chopper, which converts a higher voltage to a lower voltage at certain current levels.

The duty cycle of the DC-DC converter as well as the monitoring of voltages and currents of will be used to set the state of charge (SOC) of the batteries and monitor their SOC at all times. It will also be able to sense the amount of energy that is provided by the solar cells and ensure each energy storage medium is charged and discharged equally. Further, the terminal voltages of the energy storage mediums can be monitored to ensure they are not over-charged. The schematic for the control and data collection system is shown in Figure 4. The data attained by monitoring the state of charge of each energy storage unit will give great insight into the energy storage medium, or combinations of energy storage media, that will most efficient in the development of a near space vehicle. Fully charged batteries will also be included in the payload and not charged or discharged. Their state of charge after the experiment will be examined to determine their effectiveness to hold a charge during the flight.

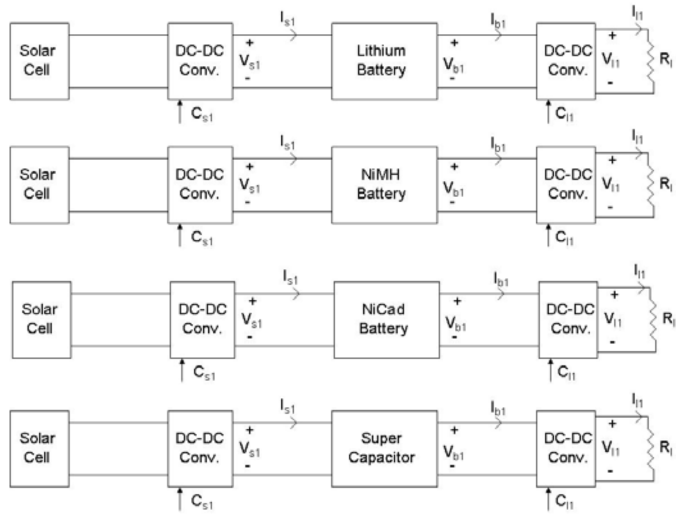


Figure 3. Main experiment for HASP payload.

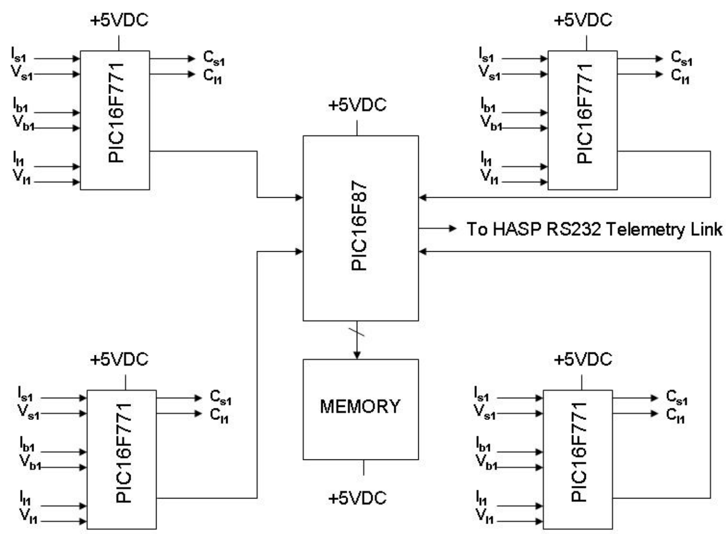


Figure 4. Control and data collection system used in the UA experiment.

WEIGHT BUDGET

The total anticipated mass for the UA-SHAPE module is 0.984 kg +/- 0.056 kg. The UA team will ensure that the final mass of the module will be under the required 1 kg mass restriction. The itemized weight budget (with uncertainties) is provided below.

Frame	310 g	+/-	25 g
8 Solar Cells	8 g	+/-	2 g
4 9V Batteris (Thermal Management Pack)	85 g	+/-	4 g
Resistor	2 g	+/-	1 g
Camera Timer Circuit	15 g	+/-	1 g
6 Data Logging Devices	276 g	+/-	6 g
Control and Telemetry Circuitry	10 g	+/-	2 g
Telemetry Interface	10 g	+/-	2 g
2 NiMH Battery	88 g	+/-	0.5 g
2 NiCad Battery	52 g	+/-	0.5 g
2 Li Ion Battery	56 g	+/-	0.5 g
2 Supercapacitors	32 g	+/-	5 g
8 DC/DC converters	30 g	+/-	2 g
Wiring	5 g	+/-	2 g
Miscellaneous (connectors/attachment points/etc)	5 g	+/-	2 g

MOUNTING FOOTPRINT

Since the UA-SHAPE module is classified as a small payload, it will have a mounting footprint of 15 cm x 15 cm.

PAYLOAD HEIGHT

Since the UA-SHAPE module is classified as a small payload, it will have a height of 30 cm.

POWER BUDGET

The 28 VDC HASP power supply will be used to power the control and data logging electronics for the experiment as well as for maintaining the thermal environment of the control chamber. Four 9V batteries will be used as a back-up power source in the unlikely event that power from the HASP is temporarily lost. The 28 V source will be regulated to 5 V using an LM7805 regulator and will be used to provide power to the controller and data collection system.

A preliminary heat transfer calculation indicates that the heat transfer rate from the sides of the control panel will be approximately 4 watts. It was assumed that the top and the bottom of the control chamber were adiabatic. For a 20 hour flight this translates into approximately 272 J. With a 28 V power supply, this implies that for thermal management the UA-SHAPE module will need 2.7 A·hr of capacity (with a current 0.135 A). It is estimated that the control and data logging electronics will need 0.25 A at 5 VDC, i.e. 1.25 W, of power for a total of 7.7 A·hr capacity for the entire UA-SHAPE module. Applying a factor of safety of 2.0, the power budget for the UA-SHAPE module is 15.4 A·hr of capacity.

DOWNLINK SERIAL TELEMETRY RATE

The UA-SHAPE module will require the use of the RS232 HASP telemetry to send the state of charge data to the student researchers (on the ground) in near real time. A memory unit will be included with master controller should the telemetry link fail. The DB9 connecter will be required to be connected to the HASP system's telemetry system so that the data can be sent to the base station via the RS232 link. This RS232 link will operate at 1200 baud, with standard RS232 protocol with 8 data bits, no parity, 1 stop bit, and no flow control. A standard packet will contain the information suggested in the Student Payload Serial Connection section of the HASP-Student Interface Document.

UPLINK SERIAL COMMAND RATE

No uplink commands will be required.

ANTICIPATED USE OF ANALOG DOWNLINKS

No analog downlinks will be required.

ANTICIPATED ADDITIONAL DISCRETE COMMANDS

No additional discrete commands will be required.

DESIRED PAYLOAD LOCATION/ORIENTATION

The requested position is one of the small payload positions on the HASP. We prefer that the 2 sides of the module containing solar cells be placed outward to receive as much solar thermal radiation as possible.

ANTICIPATED PROCEDURES

INTEGRATION

- Pre-Integration: Set data logging start time and rate
- Pre-Integration: Check state of charge of all energy storage devices
- Pre-Integration: Insert new batteries for thermal control in control chamber
- Integration: Mount UA-SHAPE module to HASP
- Integration: Connect HASP serial connector
- Integration: Connect HASP power connector
- Integration: Test system by recording state of charge data from module using HASP downlink.
- Integration: Debug any problems with above-mentioned connections or data downloading.

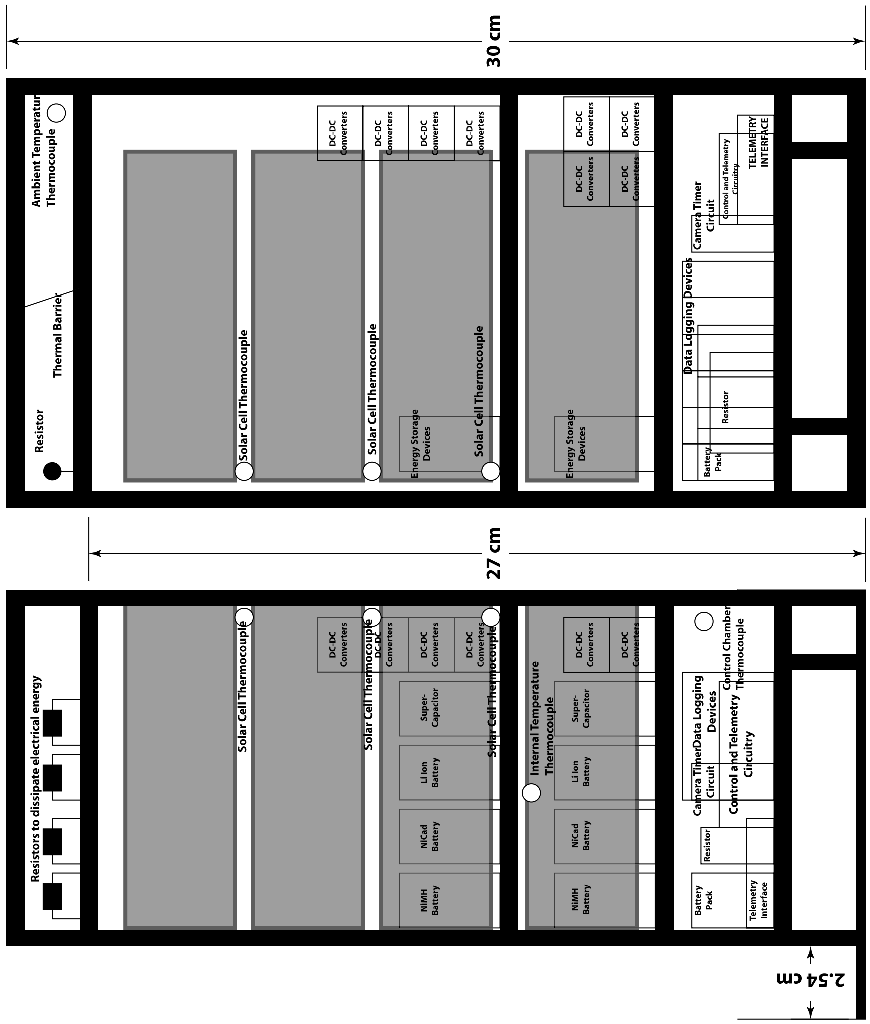
- Post-integration: Remove energy storage devices and thermal control batteries.
- Post-Integration: Remove data loggers.

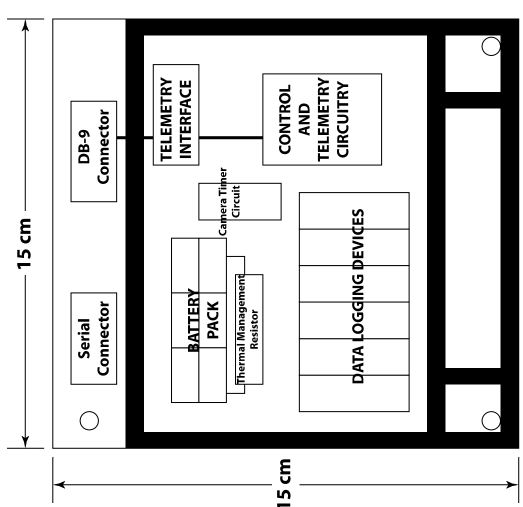
FLIGHT OPERATIONS

- Pre-Flight: Set data logging start time and rate
- Pre-Flight: Check state of charge of all energy storage devices
- Pre-Flight: Insert new batteries for thermal control in control chamber
- Pre-Flight: Connect serial connector
- Pre-Flight: Connect HASP power connector
- Flight: When allowed by HASP operations, record state of charge data from module.
- Post-Flight: Remove energy storage devices and measure state of charge.
- Post-Flight: Remove data loggers and download data

PRELIMINARY DRAWINGS

DIMENSIONED DRAWINGS

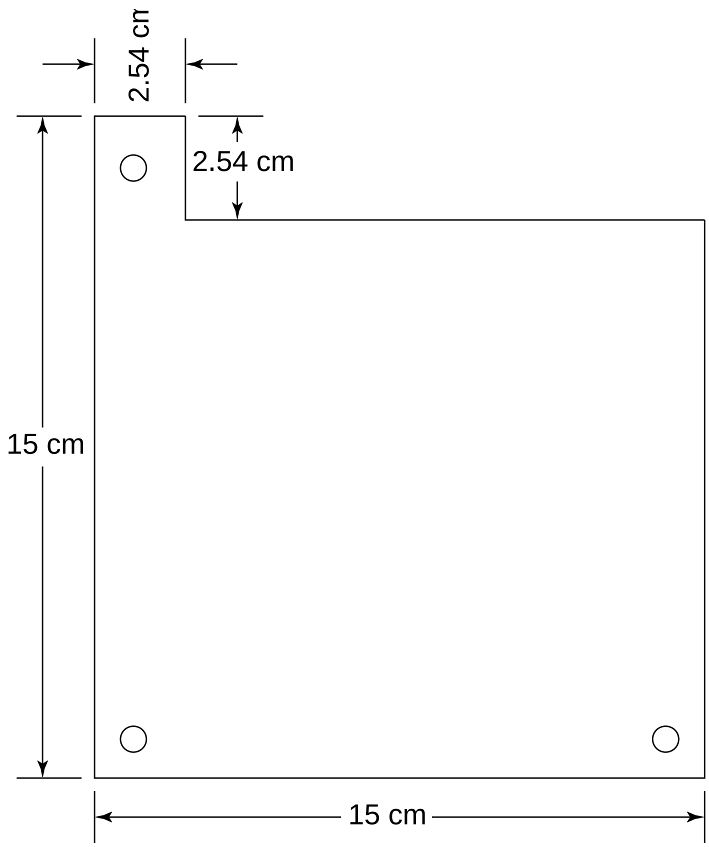




Note: The control chamber will be thermally isolated from the rest of the UA-SHAPE module.

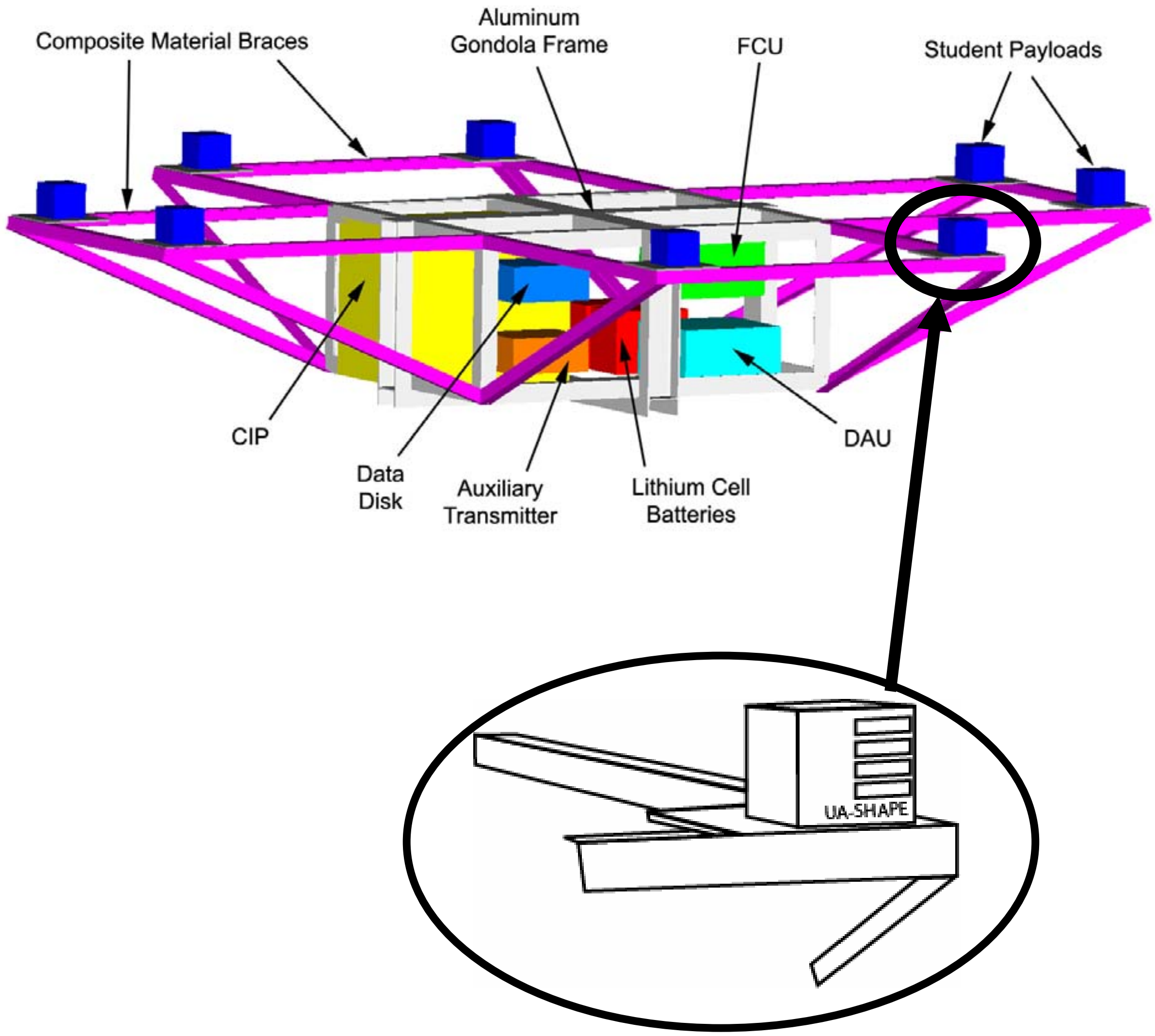
Note: In the previous schematic the gray areas are the solar cells mounted on the outside of the module. The solar cells are 11.43 cm (4.5in.) long x 3.7 cm (1.46in) wide. The mounting plate will be constructed of ¼ inch thick PVC.

MOUNTING PLATE/MOUNTING STRUCTURE



ORIENTATION RELATIVE TO HASP/LOCATION RELATIVE TO HASP

HASP image from: T. G. Guzik and J. P. Wefel, “The High Altitude Student Platform (HASP) for Student-Built Payloads", presentation to the 35th COSPAR Scientific Assembly, July 2004.



As previously mentioned, the requested position is one of the small payload positions on the HASP. We prefer that the 2 sides of the module containing solar cells be placed outward to receive as much solar thermal radiation as possible.